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THE USE OF LEAN TOOLS TO IMPROVE THE PERFORMANCE OF AN ELEVATORS COMPANY

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ABSTRACT

This paper presents a project developed in an elevators company, in the framework of a master thesis at University of Minho. The main objective of this work was to analyse the production system of one assembly section of the company and to implement some proposals that would improve its performance. This objective was achieved by applying Lean Production tools and techniques namely, 5S, Visual Management and Standard Work. With the proposed improvements it was possible to increase the shop floor area, to reduce errors and nonconformities, to reduce the number of required operators and to improve the organization of the production system. These results promoted the reduction of energy and material consumption, mainly due to the decrease of defects and reduction of rework, which are some of the requisites for a company to become eco-efficient.

Keywords: Lean Production, 5S, Visual Management, Standard Work, eco-efficiency.

INTRODUCTION

Due to the dynamic nature of the market and ever-growing customers' demand level, companies need to become competitive and able to quickly adapt to market trends, adopting new and eco-efficient production approaches. It is in this context that Lean Production appears aiming to eliminate all kinds of waste and creating value through the manufacture of quality products with minimum lead times (Womack et al., 1990).

In order to put Lean Production into practice it is necessary to implement various tools and techniques that support this organizational model, such as 5S, Visual Management or Standard Work. For several authors, the adoption of Lean tools leads to the companies' eco-efficiency. In this case, the Lean-to-Green relationship is obvious (Moreira et al., 2010). Eco-efficiency is concerned with creating more value with less impact and is a management philosophy which encourages business to search for environmental improvements that yield parallel economic benefits (Holliday et al., 2002).

The work presented in this paper was developed in a master thesis of the Industrial Engineering and Management degree at the Department of Production and Systems of University of Minho. This project was conducted in an elevators company, specifically in a section that assembles doors (landing doors and car doors). The work developed followed the Action Research methodology, i.e., a type of research characterized by an active involvement of the investigator (O'Brien, 1998) composed by five stages: (i) diagnosis, (ii) action planning, (iii) action taking, (iv) evaluation and (v) learning specification.

The main objective of this project was to improve the performance of the referred section by applying the Lean Production approach, which means reducing waste and increasing productivity and flexibility of the production system. This objective was achieved by the use of Lean tools such as Standard work, 5S and Visual Management. Additionally, balancing workloads and creating rotation plans was also helpful. As in the section analysed, many different products were assembled, it was necessary to elaborate an ABC analysis to choose a representative product, in order to make a more detailed analysis of its value chain. During this project the eco-efficiency subject was also considered.

This paper is structured in five sections. After the introduction, it is presented a brief literature review about Lean Production and its tools. Afterwards, on the third section, the assembly section of the elevators company and the problems identified are described, along with the solutions proposed to solve these problems. Then, the analysis and discussion of results is provided, and finally, in the last section, conclusions are delineated.

LITERATURE REVIEW

According to Womack et al. (1990), Lean Production is an organizational model of production that aims to eliminate waste and create value. Several authors agree that Lean Production means creating quality products with minimum lead times and that meet the customers' requirements without waste throughout the value chain (Womack et al., 1990; Spear & Bowen, 1999; Shah & Ward, 2002). Lean Production is directly related to Toyota Production System (TPS) philosophy which is based on continuous improvement and respect for people (Stewart & Raman, 2007). Womack and Jones (1996b) defined five principles that underpin Lean Production: (i) creation of value, (ii) identification of the value stream, (iii) existence a continuous production flow, (iv) implementation of a pull system and (v) pursuit of perfection. When these principles are correctly applied, they can be considered as the "antidote of waste".

The concept of waste is generally defined as any activity that does not add value to the product but that increases the cost and for which the customer is unwilling to pay (Ohno, 1988; Shingo, 1989; Womack & Jones, 1996b). Ohno (1988) and Shingo (1989) identified seven major types of waste that can exist in a production system: (i) overproduction, (ii) waiting, (iii) transportation, (iv) over-processing, (v) inventory, (vi) defects and (vii) motion.

The implementation of the Lean Production organizational model brings many benefits for companies, such as: (i) the reduction of waste, (ii) the reduction of lead time and (iii) the creation of financial savings through the reduction of costs (Melton, 2005). Several studies were conducted in order to present some of those benefits: (i) Detty and Yingling (2010) that gave an example of a company that reduced stock, occupied space, transportation, lead time and flow time; (ii) Carvalho et al. (2011) that showed the gains achieved through the creation of a well-organized pull-system, with a clean and pleasant environment.

However, these benefits can only be achieved if Lean Production has been successfully implemented, which does not always happen. This occurs mainly due to the fact that, as some studies demonstrated, the implementation of a new production paradigm depends on various specific organizational features that are not always met during the Lean implementation (White et al., 1999 and McKone et al., 1999). Shah and Ward (2002) stated that the organizational context influences the implementation of Lean practices. Moreover, Melton (2005) showed that one of the barriers to Lean implementation is that many companies still have an attitude of resistance to change and an idea that production should be about producing large batches with few variations.

In order to put Lean Production into practice, companies need to effectively implement various tools and techniques that support Lean Production (Cudney et al., 2011). Hence, some tools that may be applied are 5S, Visual Management or Standard Work. 5S is a tool that aims to ensure organization and cleanliness of the workspace in order to create a healthy environment and increase productivity (Ohno, 1988). Visual Management is a very simple tool where the language used is accessible and easily understood, allowing the operators' autonomy (Hall, 1987) and the assistance of production processes' control, preventing errors and waste (Pinto, 2009). Standard Work consists of a set of work procedures that aims to establish the best methods and work sequences for each process and for each worker (The Productivity Press Development Team, 2002). This lack of randomness in the production processes can reduce variations in cycle times, allowing companies to meet the demand's needs (Monden, 1998; Womack & Jones, 1996a).

An important aspect that has been discussed throughout the last two decades is the relationship between Lean Production and eco-efficiency. Eco-efficiency is "The delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impact and resource intensity throughout the life cycle, to a level at least in line with the Earth's estimated carrying capacity" (WBCSD, 1996). In this context, Moreira et al. (2010) present a study that shows that Lean has a positive contribution on the improvement of the environmental performance of production systems. More specifically, and related to this work, these authors give the example that the use of Lean tools contributes to, for example, to reduce overproduction and inventory, i.e., allow the consumption of less energy and materials while reducing the greenhouse gases emissions.

INDUSTRIAL APPLICATION

This project was carried out in the metal-mechanic section of a company that produces elevators. This particular section is responsible for the assembly of the elevators' doors.

According to the action research methodology, the diagnosis of the shop floor situation is the first step to take, in order to do a correct analysis. Thus, aiming to identify the problems, various diagnosis tools were used.

Since this section has many different products being assembled, it was necessary to perform an ABC analysis in order to select one of the most representatives, to execute a thorough analysis. After deciding which product would be studied, the operations of every workstation throughout the value chain were meticulously analysed with the help of different tools (e.g. sequence diagrams, time study and spaghetti diagrams). This investigation allowed the identification of several problems such as:

- High distances travelled by the operators;
- Discrepancy between cycle times – lack of line balancing;
- Disorganization of the section's supermarket;
- Large quantities of WIP;
- Production stops for lack of material;
- Lack of documentation (work procedures, components, tools);
- Cycle times exceed the takt time;
- Propensity for the occurrence of work related musculoskeletal disorders.

The long distances travelled by the operators were a problem that affected several workstations. Figure 1 shows the example of workstation 0 where the operator, while processing a single product, walks about 38 meters (m).

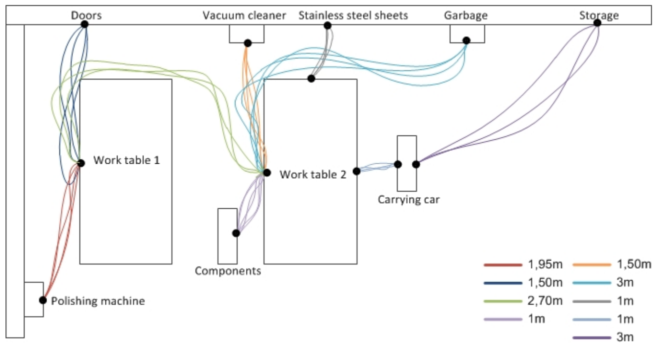


Fig.1 Spaghetti diagram for workstation 0

Equally important, was the analysis of the workers' competencies and satisfaction, using a skills matrix and a questionnaire, respectively. In general, it is possible to affirm that workers were satisfied with their jobs. However, the skills matrix revealed that most of the workers had very little capacity to adapt to other workstations besides their own, meaning that there was almost no polyvalence in the shop floor. Allied to this lack of polyvalence, there is still a problem with the standardization of production processes, which is one of the causes of nonconformities registered in the section. After developing a cause-effect diagram (to ascertain the reasons for non-compliance) it was possible to understand that human factors (errors and lack of knowledge and documentation) were fairly representative.

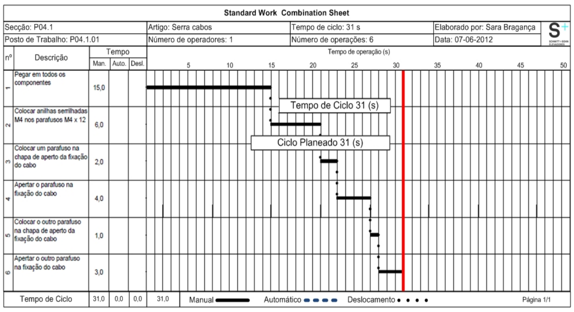
The lack of flexibility on the section, resulting from the lack of polyvalence and rotation, led to the creation of a rotation program. Since most of the sections' workstations did not have extremely low cycle times (the minimum is 10 minutes, which means that work is not excessively repetitious), and as the operators were not sufficiently polyvalent, the best option would be the implementation of an ABAB type rotation program. In such a program it is expected that the operators exchange workstation four times during the working day, each two hours, between two different workstations. Since one of the goals of creating this kind of work plan was the prevention of work-related musculoskeletal disorders (WRMSD), the workstations where the operators are must have different characteristics, e.g., a workstation where strength is needed, interspersed with a precision work workstation. Table 1 presents the classification of the workstations into three categories, according to the type of task preformed.

Table 1 Types of tasks of the various workstations

Type of task	Workstation
Strength	0, 2, 5, 10
Precision	1a, 1b, 4, 6, 7, 8
Strength and precision	3, 9

Due to the large discrepancy between the cycle times of the various workstations and also to the existence of a cycle time that exceeded the takt time, it was necessary to balance the workloads in the production line. This workload balancing was accomplished through the combination of two or more operations (that were performed in different workstations) that are now completed in a single workstation by one operator.

The variability of the manufacturing processes, the absence of a detailed sequence of work procedures and the great amount of articles, required the implementation of work standardization. The defined operations corresponded to the best and safest options, and ensure less waste in the production process. The sequence was defined taking into consideration the opinions of all stakeholders and based on predefined standard time. As the intention was to achieve a continuous production flow without excessive stock, the amount of WIP should be such that the downstream operator would have sufficient material to work. Figure 2 (a) represents an example of a standard operation combination chart created.



(a)

(b)

Fig.2 Example of (a) standard operations combination chart (b) work instruction

Work instructions often appear related to Standard Work since they document, in simplified form, standard procedures defined through Standard Work. In this sense, work instructions were created for each workstation, to describe the various steps of the production process that must be followed. Figure 2 (b) shows an example of a work instruction created for a specific workstation. These sheets are mainly based on visual information (photographs and diagrams) to simplify understanding.

In some workstations the components in the racks were much disorganized. Thus, it was decided to group the components boxes and also to place a tape to demarcate the shelf space allocated to each group. To avoid errors and reduce the components' search time, a colour was associated to each group. In Figure 3 it is possible to visualize the results of this grouping in one workstation.

Fig.3 Example of grouping components in workstations (before and after)

The disorganization of the rack of a specific workstation (workstation 4) caused the lack of three components required to assemble one product. In this particular case, the operator was forced to go to another workstation to get the components needed. To solve this problem three boxes (that contained these lacking components) were added so that the operator no longer has to go to another workstation get them.

As well as the racks, the section's supermarket was quite disorganized: (i) there were boxes containing components in excessive quantities, (ii) there was no space for all components, so they had to be dispersed over several locations, and, (iii) the boxes were placed randomly on the shelves. As such, it has become essential to restructure the supermarket. It was also reordered the way the components are organized, by grouping them by workstation. Figure 4 represents the new way of organizing the components in the supermarket. Each workstation was assigned to a colour and its components' boxes were tagged with that colour.

Fig.4 The new organization of the supermarket

Each workstation was assigned to a colour and its components' boxes were tagged with that colour.

RESULTS' ANALYSIS AND DISCUSSION

After the implementation of the proposed solutions it was possible to have some interesting results. The creation of rotation plans resulted, not only in a more interesting and motivating work, but also in an enhanced learning of new skills and in a reduction of WRMSD risk.

With the workload balancing it was possible to reduce the number of required operators, the discrepancy between cycle times and the idle time. Figure 5 shows the result of the line balancing intervention. This balancing was achieved by combining two or more operations (which were performed in different workstations) that are now performed by the same operator. However, as can be seen in the Figure 5, this balancing presents a case where the cycle time is 1.15 minutes longer than the takt time. Though, this was the best result that could be obtained without splitting the operations too much. As it is a not very significant value, mutual assistance between operators could easily solve this problem.

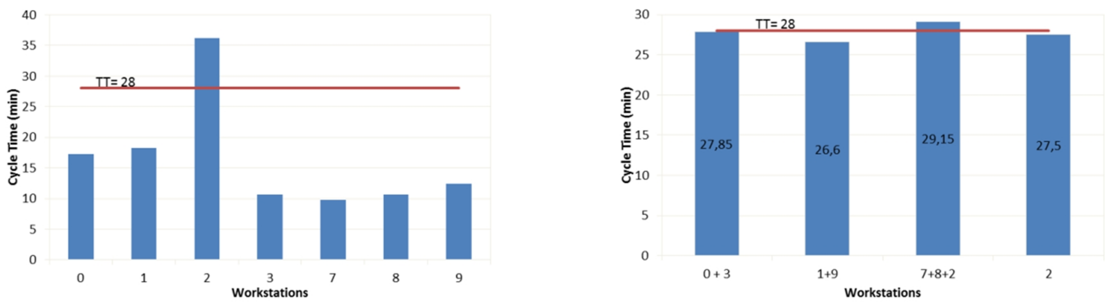


Fig.5 Result of the line balancing (before and after)

The standardization of work procedures enabled the reduction of errors, nonconformities and even the number of complaints received. It was also observed a reduction in the need for assistance (operators with doubts about the assembly) and the teaching of new operators for the section was facilitated, since an assembly guide was available.

The use of the Lean tools 5S and Visual Management allowed savings in terms of cycle time, distances travelled by the operators and space occupied in the shop floor. Regarding the availability of space, a good example of the improvements achieved is the increase of 50% in the capacity of the section's supermarket. Concerning cycle times, Table 2 shows three examples of gains accomplished by the use of 5S and Visual Management.

Table 2 Gains in cycle time after 5S and Visual Management implementation

Workstation	CT before (min)	CT after (min)	Gain (%)	Distance travelled before (m)	Distance travelled after (m)	Gain (%)
0	5	1	80	-	-	-
1	1	0	100	15	0	100
4	2.5	0	100	75	0	100

Additionally, with these two Lean tools, it was possible to create an environment with visual information and less confusion, simplifying the operators' tasks and reducing unproductive time, possible errors in production and the need for rework. The implementation of 5S and Visual Management in a specific workstation demonstrates a clear example of the gains in monetary terms it was possible to obtain. Table 3 shows the number of units it is possible to produce more than previously, the time gained (that was formerly spent not adding value) and the money that can be saved per year with just this modification.

Table 3 Financial gains after 5S and Visual Management implementation in workstation 2

Man-hour cost	9.30 €/h
Number of units that can be produced per day	11 units
Time gained per day	66 minutes
Gains per year	18,905.04 €/year

These gains, allied with the savings in energy and material consumption, promoted production cleanliness to achieve the Lean-to-Green relationship.

CONCLUSIONS

This study intended to demonstrate the benefits that a company may obtain by the implementation of Lean Production. This project was carried out in a metal-mechanic section of an elevators company, in the context of a master thesis project in Industrial Engineering and Management. After analysing the production system and identifying areas that needed to be improved, various Lean tools (5S, Visual Management and Standard Work) were applied.

Often, solutions that seem simple can bring great improvements at low cost if applied correctly. The proposals suggested for the problems found met the planned objectives. Most of these suggestions had as goal the overall improvement of the section's performance through the use of three main tools – 5S, Visual Management and Standard Work – that allowed the creation of documents and the achievement of a better shop floor organization. The use of these Lean tools enabled the production cleanliness, less rework and material consumption, energy savings and, primarily, a culture of waste-free environment that promote an eco-efficient company.

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